UNIT-I
MAINTENANCEANDREPAIRSTRATEGIES

TWO MARKS QUESTIONS AND ANSWERS

1. What do you mean by deterioration? (NOV/DEC 2008)

The process that adversely affects the performance of a structural over time due to detects and damages occurred by naturally occurring chemical, physical or biological actions, repeated actions such as those causing fatigues, normal or severe environmental influences.

2. Write short notes on the importance of maintenance. (MAY/JUNE 2009)

- improves life of building
- Improved life period gives better relation on investment
- Better appearance and aesthetically appearing
- Prevents major deterioration and leading to collapse

3. What do you mean by structural cracks? (MAY/JUNE 2009)

Structural cracks due to incorrect design, faulty construction or overloading. For example, Extensive cracking of a RCC beam.

4. Why is Inspection needed for damaged structures? (NOV/DEC 2011)

Occurrence of deterioration and or change in its performance of a structure should be detected through inspection. The initial inspection is carried out before the structure is put into operation after completion of construction. Detailed inspection is carried out to obtain detailed and specific information of the structure.

5. What is maintenance? (MAY/JUNE 2010)

The term maintenance comes from the French verb Maintainer which cannot to hold. It means to hold, keep, sustain or preserve equipment, building or structure to an acceptable standard of serviceability.

6. What are the objectives of maintenance? (NOV/DEC 2011)

- To preserve buildings
- To restore buildings
- To make improvement in serviceability

7. **What are the factors influencing maintenance?**

There are various factors which influence the decision to carryout preventive or corrective maintenance. Therefore it is necessary to consider these factors for effective maintenance of building:

i) Cost, ii) Age of building, iii) Availability of physical resources, iv) Urgency of maintenance, v) Future use and vii) Social considerations.

8. **Define the following terms**

i) Repair,

ii) Retrofit,

iii) Rehabilitation,

iv) Restoration (NOV/DEC 2007)

(i) Repair

Actions that improve the functioning of a member of a structure. The member is lighter defective or deteriorated or damaged due to any reason such as earthquakes, cyclone, flood, fire, explosive, vehicle collisions, corrosion cracking, insect infestation etc. The action may not be intended regain the original strength of the member completely.

(ii) Rehabilitation

Actions that improve the strength of a structure or a member which is deteriorated or damaged due to various reasons. Rehabilitation includes repair. The action is intended to regain the original strength of the structure or member.

(iii) Retrofit

Actions that improve the strength and other attributes of the integrity of a structure or a member with respect to resisting seismic forces. The structure or member need not be deteriorated or rehabilitation. The action is intended to mitigate the effects of future earthquakes.

(iv) Restoration

Actions that improve the strength and appearance of a structure. The term is used mostly for historical structures. Restoration may include repair for a deterioration or damaged structure

9. Define Maintenance.

Maintenance is the net of keeping something in good condition by checking or repairing it regularly.

10. Define Repair.

Repair is the process of restoring something that is damaged or deteriorated or broken, to good condition,

11. Define Rehabilitation.

Rehabilitation is the process of returning a building or an area to its previous good conditions,

12. What are the two facets of maintenance? **(NOV/DEC 2009)**

The two facets of maintenance are

(i) Prevention

(ii) Repair

13. What are the causes of deterioration? **(MAY/JUNE 2009)**

i) Deterioration due to corrosion

ii) Environmental effects

iii) Poor quality material used

iv) Quality of supervision

v) Design and construction flaws

14. Define physical inspection of damaged structure.

Some of the use full information may be obtained from the physical inspection of damaged structure, like nature of distress, type of distress, extent damage and its classification etc, their causes preparing and documenting the damages, collecting the samples for laboratory testing and analysis, planning for in situ testing, special environmental effects which have not been considered at the design stage and information on the loads acting on the existing structure id the time of damage may be, obtained. To stop further damages, preventive measure necessary may be planned which may warrant urgent execution.

15. How deterioration occurs due to corrosion?

- Spoiling of concrete cover
- Cracks parallel to the reinforcement
- Spalling at edges
- Swelling of concrete
- Dislocation
- Internal cracking and reduction in area of steel reinforcement.

16. What are the steps in selecting a repair procedure?

- Consider total cost
- Do repair job in time
- If defects are few and isolated repair on an individual basis. Otherwise do in generalized

17. Discuss about the environment effects which leads to deterioration of concrete structure.

Micro cracks present in the concrete are the sources of ingress of moistures atmospheric carbon di-oxide into the concrete which attack reinforcement and with various ingredients of concrete. In aggressive environment concrete structure will be severely reduced.

18. What is the effect of selecting poor quality material for construction?

(MAY/JUNE 2009)

Quality of materials, to be used in construction, should be ensured by means various teats as specified in the TS codes. Alkali-aggregate reaction and sulphate attack results hi early deterioration. Clayey materials in the fine aggregates weaken the mortar aggregate bond and reduce the strength. Salinity causes corrosion of reinforcing bars as well as .deterioration of concrete.

19. How can we determine the cause far deterioration of concrete structure?

a) Inspect and observe the structure

b) Observe in bad and good weather

29. What are the factors that affect cracking?

- Water
- Cement
- Aggregate
- Bleeding
- Improper curing
- Exposure
- Cover

SIXTEEN MARKS QUESTIONS AND ANSWERS

1. Describe the steps in the assessment procedure for evaluate damages in a structure.

The following steps may be necessary

a) Physical inspection of damaged structure.

b) Preparation and documenting the damages.

c) Collection of samples and carrying out tests both in situ and in laboratory.

d) Studying the documents including structural aspects.

e) Estimation of loads acting on the structure

f) Estimation of environmental effects including soil structure integration.

g) Taking preventive steps not to cause further damage

h) Retrospective analysis to get the diagnosis confirmed

i) Assessment of structural adequacy

j) Estimation on future use

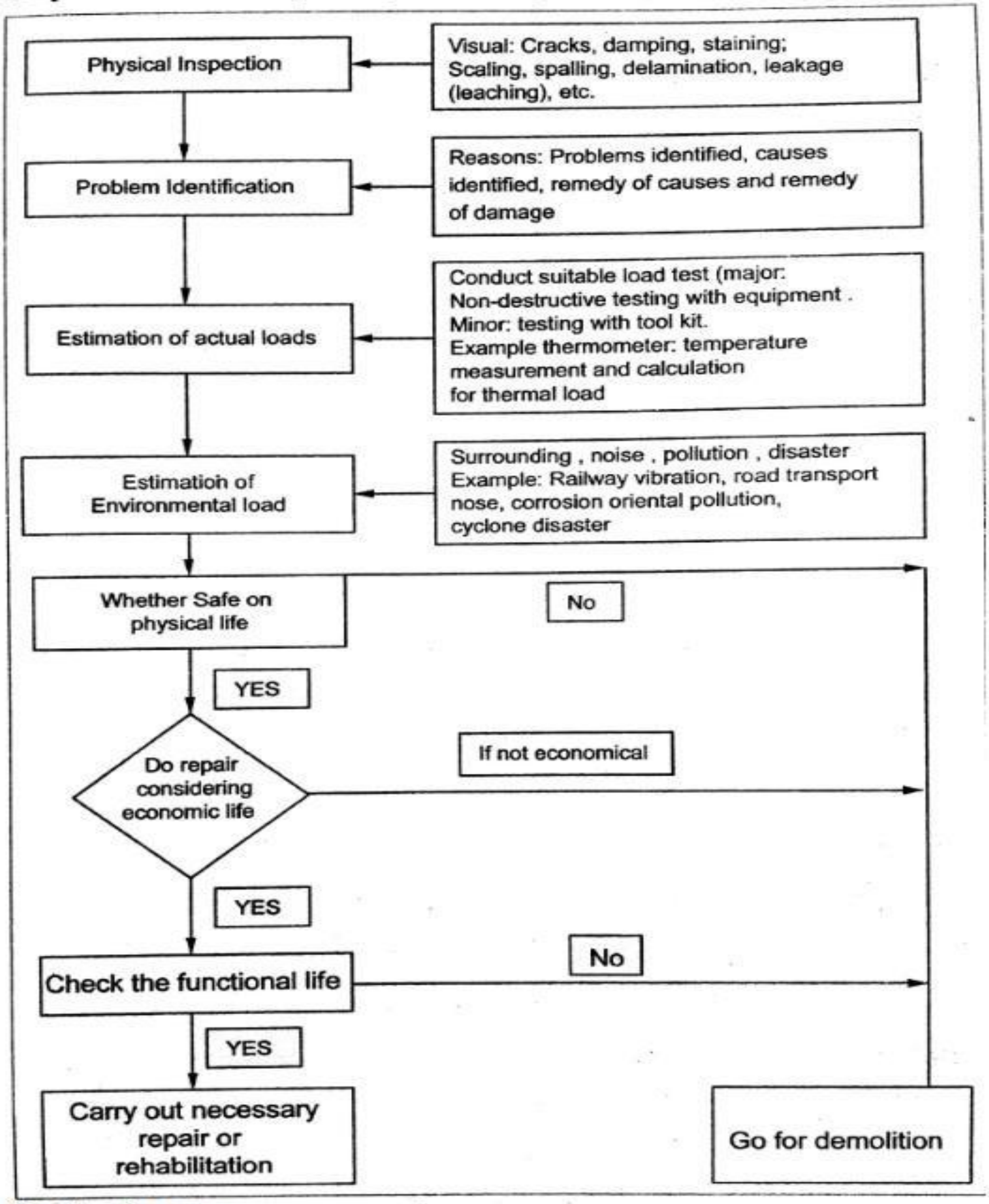
k) Remedial measures necessary to strength and repairing the structure.

l) Post repair evaluation through tests

m) Load test to study the behavior

n) Choice of course of action for the restoration of structure.

A simple flow chart incorporating the above points is presented in Figure.



2. Explain the various causes for deterioration of concrete structures.

Some of the causes of deterioration of concrete structures are discussed below,

a. Design and construction flaws

Design of concrete structures governs the performance of concrete structures. Well designed and detailed concrete structure will show less deterioration in comparison with poorly designed and detailed concrete, in the similar condition. The beam-column joints are particularly prone to defective concrete, if detailing and placing of reinforcement is not done properly. Inadequate concrete cover may lead to carbonation depth reaching up to the reinforcement, thus, increasing the risk of corrosion of the reinforcement.

b. Environmental effects

Micro-cracks present in the concrete are the sources of ingress of moistures, atmospheric carbon di-oxide into the concrete which attack reinforcement and with various ingredients of concrete. In aggressive environment concrete structure will be severely affected.

c. Poor quality material used

Quality of materials, to be used in construction, should be ensured by means of various tests as specified in the IS codes. Alkali-aggregate reaction and sulphate attack results in early deterioration. Clayey materials in the fine aggregates weaken the mortar aggregate bond and reduce the strength. Salinity causes corrosion of reinforcing bars as well as deterioration of concrete.

d. Quality of supervision

Construction work should be carried out as per the laid down specification. Adherence to specified water-cement ratio controls strength, permeability, and durability of concrete. Insufficient vibration may result in porous and honey combined concrete, whereas excess vibration may cause segregation.

e. Deterioration due to corrosion

- Spalling of concrete cover
- Cracks parallel to the reinforcement
- Spalling at edges

- Swelling of concrete
- Dislocation
- Internal cracking and reduction in area of steel reinforcement.

3. Describe in detail about the prevention aspect of maintenance.

Of the two considerations - prevention and repair, prevention is more important.

During construction the defects that may seem minor, will have serious consequences. The design engineer is responsible for the selection of proper materials suitable for the exposure conditions of site, detailing of the structure in a manner to prevent serious deterioration atleast for the assumed service life and through the inspection staff must insist on proper construction.

These three points — proper materials, proper details, and proper construction require knowledge of what is improper at a site or construction; about the various ways of deterioration and about their causes. But there are some general considerations that should be taken into account for both the construction of new concrete structures and the repair of deteriorated structures. They are as follows.

a. Match the materials to the environment

Durability becomes an issue when a material's resistance to deterioration is less than that required to withstand the aggressiveness of the environment in which it is to function. For example, Steel will not corrode in a dry, and salt free environment, but it will do so in the presence of moisture and chloride ions.

To ensure the choice of an appropriate material, the environmental conditions to which the material will be exposed must be known so that its behaviour under these conditions can be predicted and addressed in the design. When a designer contemplates using a new material, problems may arise if there has not been sufficient experience with the material to adequately understand its behavior or to allow for the development of standards.

In the absence of standards, several factors should be critically evaluated, among them the relevance of the test data provided in product literature, and the limitations and requirements associated with the environmental conditions of the project.

The following factors should be considered by the designer at the construction site.

- Minimum and maximum temperatures
- Temperature cycles

- Exposure to ultra violet radiation
- Amount of moisture
- Wet/dry cycles
- Presence of aggressive chemicals.

b. Combine only materials with similar properties

Concrete is a solidified mixture of diverse materials. When these materials are incompatible with one another, the concrete cracks and spalls, resulting in unsightly surfaces and the need of expensive rehabilitation work. Materials are considered to be incompatible when the differences in their physical of chemical properties exhibit a state of instability.

For example, Galvanic corrosion is promoted when two metals with different electrochemical properties are combined in a building assembly.

The use of materials with different thermal coefficients or different modulli of elasticity should also be avoided, since they expand and contract at different rates, and their deformation characteristics are significantly different. In both instances, the incompatibility of the selected materials will lead to deterioration of the concrete. When the load is perpendicular to the bond line, the difference in modules does not cause problems. However, when it is parallel to the bond line, deformation of the material with the lower modulus transfers load to the material with the higher modulus, which may then fracture.

c. Assess the limitations of a particular material in its functional context

The selection of materials, particularly those used in repairs, must be based on knowledge of their functions and of the environment in which the materials have to function. Their physical and chemical properties as well as their limitations with respect to installation and performance must also be considered. In particular, the designer should anticipate the degree of abrasion or wear to which a surface will be subjected. For eg: Parking garages should be designed to resist more abrasion by using special cast concrete and on applied polymeric coating impregnated with an abrasion - resistant material such as corundum.

In choosing a material the designer should be aware not only of the properties that seem to address the intended function but also the auxiliary properties that did not constitute the basis for selecting the material. For eg: Air entrainment is used to provide durability with respect to freeze and thaw cycles but it also enhances workability.

d. Protect materials from general deterioration

Most concrete deterioration can be attributed to water penetration since concrete absorbs moisture until it become, saturated, preventing entry of water from collecting on surfaces is of prime importance. Moisture fosters deterioration not only where it carries dissolved chemicals that can react with steel, lime and other components in the concrete, it also plays a major role in concrete deterioration through freeze thaw eyries. By providing sufficient slopes and effective drainages, it is possible to prevent water from ponding and thus being absorbed. Concrete design should accentuate water shedding characteristics for vertical elements. For eg: proper window shades prevent the wall from wetting. Sealing the surface with a penetrating concrete sealing and the use of 50 mm thick reinforcement cover to protect steel are other means of protection.

e. Design level Factors

Concrete structures are an assembly of operating systems that experience temperature, air pressure and vapour pressure and gradients. Seasonal and dismal fluctuations on outdoor conditions provide variability and direction of the gradients. These operating conditions can accelerate premature failure of the components in a repair. The relative severity of these factors will vary depending on the use and location of the structure, and the types of repair material used and so on. Predicting these fluctuations and accommodating them at design stage is important.

f. Allow for change in use in design

During the service life of a structure, its environment and occupancy may change. As a result, the structure will have to withstand stresses different from those for which it was originally intended.

For e.g.: Addition of roof garden to parking lot requires additional protection against ponding of water on the roof of parking lot.

4. Describe in detail about the repair aspect of maintenance

Even though designers allow a large margin of safety in their designs, once deterioration reaches a critical limit, immediate repair is needed to restore the level of performance to its intended level of service. In fact, if the rehabilitation work is not carried out in time, the structure may not be repairable to the required level of service. The execution of such a repair is an exacting, technical matter involving five basic steps.

1. Finding the deterioration
2. Determining the cause
3. Evaluating the strength of existing building or structure
4. Evaluating the need of repair
5. Selecting and implementing a repair procedure

a. Finding the deterioration

Before the repair can be effected, there must be a realization that something is wrong, and the realization must come before it is too late to make a repair, i.e., before the structure has collapsed.

For example, timbers and timber piling can be damaged by insects or marine organisms, virtually to the point of collapse, without exhibiting any external evidence which would be apparent except to a trained observer. Even a common defect like corrosion of steel can be difficult to detect because if it occurs, principally, in the most inaccessible parts of the structure. The reason is simple. The accessible parts are painted, but the inaccessible parts often are neglected.

The point to be made is that the engineer charged or interested in maintenance must be trained, technically in, where to look, how to look and what to look for, before he can even be expected and realize that there is trouble. Knowing all these requires knowledge of various kinds and causes of deterioration and before checking, the engineer must know all these.

b. Determine the Cause

To select the repair step, the cause has to be identified. In case of concrete, the specific cause might not be known due to several agents acting. What can be done is to eliminate possibilities and design repair procedures for any of the remaining part of the structure. In such cases the cost will go higher. But it should also be noted that the failure to understand the cause of a defect can lead to the selection of a repair procedure which would be harmful, rather than helpful. There are no set rules for determining the cause but with experience you can determine. For eg: cracks in walls due to foundation settlements run diagonally.

Cracks due to corrosion of reinforcement run straight and parallel at uniform' intervals and show evidences of rust, and staining

A few tips are as follows:

(a) Inspect and observe the structure

(b) Observe in bad and good weather

(c) Compare with other constructions in the area or elsewhere and be patient

(d) Study the problem and allow enough time to do the job.

c. Evaluate the strength of the Existing structure

This should be done to know whether it is safe to continue using the structure or limit it to a less severe extent of usage if the structure has not completely deteriorated, the adequacy of determination of strength becomes important. For this the following methods can be used.

(i) Fixed percentage method

It is to be assumed that all members who have lost less than some predetermined % of their strength are still adequate and that all members who have lost more than the strength are inadequate. It is usually from 15% onwards; higher values are applicable for piling, percentage stiffness bearing plates etc.

(ii) Analysis of the Actual stress condition

This method is to make detailed stress analysis of the structure, as it stands including allowances for loss of section where it has occurred. This is more difficult and expensive. Here also the first step is to make preliminary analysis by fixed percentage method and if it appears that major repairs will be required, the strength is revaluated based on detailed stress analysis, considering all contributions to such strength.

(iii) Load test

Third step is load test. Load tests may be performed according to the building codes. But they should only be performed where computation indicated that there is reasonable margin of safety against collapse, lest the test bring the structure sown. Load test show strengths much greater than computed strengths when performed on actual structures. In repair work every little bit of strength is important.

Accordingly the use of load test is recommended but with a full and clear understanding of their limitations and range of applicability.

d. Evaluate the need of repair

When the cause of the deterioration has been determined and the strength of the existing structure has been checked, a decision must be made whether.

(i) To permit deterioration to continue

(ii) To take measures to preserve the structure in its present condition without strengthening.

(iii) To strengthen the construction

(iv) If deterioration is exceptionally severe to reconstruct or possibly abandon it.

These decisions are based on:

(a) Safety

(b) Economy and

(c) Appearance

Different decisions may be appropriate for different elements of the same structure.

Case (a): Analysis show that structure still has adequate strength:

- If the appearance of the existing condition is objectionable - repair now
- If appearance is not a problem then
- Put the condition under observation to check if it is dormant or progressive.
- If dormant - no repair
- If progressive - check the feasibility and relative economics of permitting deterioration to continue and performing a repair at some later date or making the repair straight away.

Case (b) Analysis shows that the strength of the structure currently is inadequate:

- Either repair it or
- Rebuild it or

- Abandon it, partially or completely or
- Consider a change of use.

e. Select and implement a Repair procedure

- Select the least expensive that can suit the job

Steps of Repair

- Consider total cost
- Do repair job in time
- If defects are few and isolated repair on an individual basis. Otherwise do in generalized manner.
- Ensure that the repair prevents further development of defects
- In case of lost strength, repairs should restore the strength
- If appearance is a problem, the number of applicable types of repairs becomes limited and the repairs must be covered.
- Repair works should not interface with facilities of the structure.
- Take care in addition of section to a member and in redistributing live loads and other live load moments. After selecting a suitable method of repair, and after considering all the ramifications of its application, the last step is to prepare plans and specifications and proceed with the work.

5. Explain in detail about the permeability of concrete.

- Since concrete is permeable and porous in nature, the liquid and gases can move inside the concrete and is called "Permeability" i.e., the liquids and gases that can move in the concrete is determined by its permeability.
- Thus the permeability is much affected by the nature of the pores, both their size and the extent to which they are inter-connected.

Characteristic study of permeability

- The hardened cement paste consists of gel pores to the extent of about 28% but the gel pores are so small so that no water can pass through under normal conditions. The permeability of gel is 1/100 of that of paste. Therefore the gel pores don't contribute to the permeability of concrete.

Causes

The higher permeability of concrete structure is due to:

- Formation of micro-cracks due to long term drying shrinkage.
- Rupture of internal face, bond between aggregate and paste.
- Due to volume change caused in the concrete on account of various minor reasons.
- Existence of entrapped air due to insufficient compaction.

Control of permeability

- The use of pozzolanic materials in optimum proportions will reduce permeability.
- Though air entrainment makes the concrete porous, use up to about 8% makes concrete more impervious contrary to general relief.

Effects of permeability on concrete reinforcement steel

- The permeability of moisture or gas is important in relation with the protection afforded to the embedded steel.
- The reaction of water with the steel bars is such that the bars way is corroded (and rusting of steel occurs).

Effects of permeability on concrete

- Permeability characteristics of concrete are of greater bearing on its durability.
- The penetration of aggressive liquid or gas in concrete depends upon the extent of the degree of permeability of concrete.
- The permeability characteristics of concrete (hardened) consist of gel pores and capillary cavities. The gels are pores to the extent of about 28% but the gel pores are so small that hardly any water can pass through under normal conditions. The permeability of gel is 1/100 of that of paste. Therefore the gel pores don't contribute to the permeability of concrete whereas the capillary cavities depend on the W/C ratio. This is one of I the main factors contributing to the permeability of concrete.

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UNIT- II STRENGTH AND DURABILITY OF CONCRETE

TWO MARKS QUESTIONS AND ANSWERS

1. **How can we prevent the effect of freezing and thawing in concrete?**

   Concrete can be restricted from frost action, damage of the structure by the entrainment of air. This entrainment of air is distributed through the cement paste with spacing between bubbles of no more than about 0.4 mm.

2. **Write any two tests for assessment of frost damage.**

   The frost damage can be assessed by several ways:

   (i) Assessment of loss of weight of a sample of concrete subjected to a certain number of cycles of freezing and thawing is one of the methods.

   (ii) Measuring the change in the ultrasonic pulse velocity or the damage in the change in the dynamic modulus of elasticity of specimen is another method.

3. **How does a concrete structure get affected by heat?**

   Heat may affect concrete as a result of:

   - The removal of e vapor able water
   - The removal of combined water
   - Alteration of cement paste
   - Alteration of aggregate
   - Change of the bond between aggregate and paste

4. **How can you control cracks in a structure?**

   - Use of good coarse aggregates free from clay lumps
   - Use of fine aggregate free from silt, mud and organic constituent.
   - Use of sound cement.
   - Provision of expansion and contraction joint.
   - Provide less water-cement ratio.

5. **Define aggregate splitting.**

   This phenomenon occurs most frequently when hard aggregates are used in concrete. The thermal stresses except close to corners are predominantly compressive near to the heated surface. This stress causes the aggregate to split in this direction and the fractures may propagate through the mortar matrix leading to deterioration.

6. **Write the factors affecting chemical attack on concrete.**

- High porosity
- Improper choice of cement type for the conditions of exposure
- Inadequate curing prior to exposure
- Exposure to alternate cycles of wetting and drying

7. **Write the methods of corrosion protection.**

- Corrosion inhibitors
- Corrosion resisting steels
- Coatings for steel
- Cathodic protection

8. **List out some coating for reinforcement to prevent corrosion.**

- Organic coating
- Epoxy coating
- Metallic coating
- Zinc coating

9. **Define comer separation.**

This is a very common occurrence and appears to be due to component of tensile stress causing splitting across a comer. In fire tests, comer separation occurs most often in beams and columns made of Quartz aggregate and only infrequently with light weight aggregates.

10. **List any four causes of cracks.**

- Use of unsound material
- Poor and bad workmanship
- Use of high water-cement ratio
- Freezing and thawing
- Thermal effects.
- Shrinkage stresses.

11. What are the types of cracks?

(i) Class-1: Cracks leading to structural failure

(ii) Class-2: Cracks causing corrosion

(iii) Class-3: Cracks affecting function

(iv) Class-4: Cracks affecting appearance

12. What changes occur, when hot rolled steel is heated to 500"C?

At temp of 500°C - 600°C the yield stress is reduced to the order of the working stress and the elastic modulus is reduced by one-third. Bars heated to this temperature virtually recover their normal temperature.

13. List out the various types of spalling.

(i) General or destructive spalling

(ii) Local spalling which is subdivided as

- Aggregate splitting
- Surface spalling
- Sloughing off

14. List some faults in construction planning.

- Overloading of members by construction loads
- Loading of partially constructed members
- Differential shrinkage between sections of construction
- Omission of designed movement joints

15. Define corrosion.

The gradual deterioration of concrete by chemically aggressive agent is called "corrosion".

16. Give some examples for corrosion inhibitors.

(i) Anodic inhibitors

(ii) Cathodic inhibitors

(iii) Mixed inhibitors

(iv) Dangerous and safe inhibitors

17. Define effective cover.

The cover to reinforcement measured from centre of the main reinforcement up to the surface of concrete in tension is called "Effective cover".

18. Define corrosion inhibitor.

Corrosion inhibitor is an admixture that is used in concrete to prevent the metal embedded in concrete from corroding.

19. What are the operations in quality assurance system?

- Feed back
- Auditing
- Review line
- Organization

20. List the various components of quality control.

Five components of a quality (control) assurance system are:

- Standards
- Production control
- Compliance control
- Task and responsibilities and
- Guarantees for users.

21. List any four durability parameters.

- Acid test
- Alkali test
- Carbonation test
- Salt attack test
- Sulphate attack test

22. Discuss the effect of temperature on concrete.

In mortar and concrete, the aggregates undergo a progressive expansion on heating while the hydrated products of the set cement, beyond the point of maximum expansion shrinks those two opposing actions progressively weaken ad crack the concrete. Quartz, the principal mineral in sand, granites and gravels expands steadily up to about 573°C. At this temperature it undergoes a sudden expansion of 0.85%. This expansion has a disruptive action on the stability of concrete.

23. Explain the mechanism of cathodic protection.

In cathodic protection the corrosion of steel embedded in concrete it controlled by applying a direct current to the embedded steel before an external source. An electric current is applied to the concrete anode and the embedded steel. This action forces the steel in the concrete 'to becomes cathodic, which provides the protection. This is the only method to stop on going corrosion in a concrete structure. This method is well suited for chloride induced corrosion problem cathodic protection is not recommended for carbonated concrete. This is because the carbonation increases the resulting of the concrete making it more difficult to impose and electric current

24. Discuss briefly the effects due to climate.

It is defined as changes in color, texture, strength, chemical compositions, or other properties of a natural or artificial material due to the action of the weather. The environmental factors can cause cracking include freezing and thawing, wetting and drying, cooling and heating.

25. Classify cracks based on its thickness

The internal stresses within the repair material and substrate are affected not only by the differential movements, but also by the relative thickness a thinner repair flayer is more easily cracked or deboned by the higher tensile stress which occurs in the repair material.

26. Explain the importance of co-efficient of thermal expansion with respect to strength of concrete?

Tensile stress in the repair materials caused by in the changes in the temperature of the surrounding environment is proportional to the difference in the co-efficient of thermal expansions and the changes in the temperature. The repair materials selected should have a similar a co-efficient of thermal expansion as the substrate as possible.

27. What are the steps to be taken to prevent corrosion of reinforcement?

- Use of concrete with low permeability
- Use of properly proportioned concrete having a low w/c ratio
- Use of as low a concrete slump as practicable
- Curing of concrete properly
- Providing adequate concrete cover over the reinforcing steel.

28. Discuss the importance of quality control?

Corrosion initiation is largely influenced by the quality of concrete especially in the coyer region; both physical and chemical parameters of concrete need to be considered. The Primary chemical parameters are its alkalinity expressed in terms of its pH value. The alkalinity is provided by the pore solution of concrete which is basically calcium hydroxides. A pH value of more than 12.0 using proper cement content and concrete quantity will be necessary.

29. Explain the difference between "wear and erosion"?

- "Abrasion refers to earning way of the surface by friction
- Erosion refers to wearing away of the surface by fluid
- If the aggregate in concrete is wear resistant, the properties of the cement matrix control the abrasion resistance.

30. Give one example in each for corrosion inhibitor and corrosion coating?

Corrosion inhibitor:

- The addition of calcium nitrate extends the time to corrosion initiation
- The corrosion rate, once corrosion is initiated is less with calcium nitrate
Corrosion coating
- Coating of reinforcement
- Galvanized reinforcement
- Stainless steel reinforcement.

SIXTEEN MARKS QUESTIONS AND ANSWERS

1. Explain in detail about quality assurance.

Quality assurance scheme is a management system which increases confidence that a material product or service will conform to specified requirements.

Functions of quality assurance

It outlines the commitment policies, designated responsibilities and requirements of the owner. These are then implemented through quality assurance programme to provide a means of controlling to predetermined requirements. These activities, which influence quality in the manufacture of virtually every complex product, a quality assurance scheme of one typo or another is used.

Factors influencing Quality Assurance

Depending upon the value of the product and methods used, such scheme may become extremely complex, so that it cannot be guaranteed in all cases for all the functional requirements.

The need for quality assurance

In the construction of concrete structures quality assurance is necessary to give good performance and appearance throughout its intended life is attained.

It is useful for promoting the quality control schemes by engineers. The designer depends upon this for reputation and professional competence.

Causes for poor quality control

Misinterpretation of design and drawings or other specifications, lack of effective communication with suppliers and co-contractors inefficient coordination or sub-contracted work, inadequate on-site supervision, poor workmanship due to inadequate skills and experience of the labour force, quality control will suffer.

Factors affecting structural failure due to lack of:

- Communication and organization in construction industry.
- Inspection of construction by the structural engineer.
- General Quality of design.
- Design details and shop drawings.

- Timely dissemination of technical data.

Development and operation of quality assurance system

The basic mechanism available for both the development and operation of a quality management system.

(i) **Organization:** Which requires clear definition of responsibilities and relationship for the total construction project.

(ii) **Auditing:** Which requires the ability to determinate that the tasks defined under responsibilities are continuously being executed according to stated methods.

(iii) **Review line:** Which requires continuous checks on process methods and action procedures adopted if stated requirements are not being met

(iv) **Feed back:** Which requires deduction in measurable terms of causes of errors that generate defects, in order that processes can be changed so as to reduce non-conformance and the benefit of such change to be demonstrated.

Design Procedure

- Recognition that a quality management system cannot compensate for conceptual error or inadequate specifications. The system merely aims for consistent application of procedures to meet the specification.
- Concern at the cost of introducing and maintaining a management system without reassurance of consequential benefits.
- Doubts on the effectiveness of a quality management system design. In particular doubles that quality assurance procedure for manufacturing process may not be appropriate for design service.

2. Describe the various components of quality control.

Five components of a quality (control) assurance system are:

- Standards
- Production control
- Compliance control
- Task and responsibilities and
- Guarantees for users

Standards or specifications

- ❖ Standards or specifications are used to define the important criteria, methods of assessment or testing and levels of acceptance to satisfy the tested (component) requirement.
- ❖ They should, if possible be expressed in performance terms.
- ❖ In connection with the specifications, it should be noted that the only good specification is that which requires only those things that need to be done make concrete suitable for its purpose.
- ❖ A good specification contains no requirements that can be ignored.

Production or internal control procedure

- ❖ Production or internal control procedure requires to be done by each of the parties to confirm that its own personal and operations are conforming to its own quality control standards.
- ❖ Internal control is generally undertaken on a regular basis by the person responsible for the particular operation.

Compliance or acceptance control procedure

- ❖ Compliance or acceptance control procedures are required to be applied to the material and to the structural members at the end of each constructional operation.
- ❖ It is often the duty of the person who is to continue the work on the resultant product to check such compliance it may be done at critical stages by an independent authorized body during regularity inspections.
- ❖ Compliance or acceptance control may also be undertaken by the design engineer and in this case, a problem of costs for more regular inspection of work than its usual may arise.
- ❖ Unfortunately no universal scheme for inspection for the stages of construction can hope to cover the many variations observed on site.
- ❖ Probably the most connecting evidence of all conducted inspections lies in the documentation which forms the inspection records.

Inspection records

- ❖ The inspection records should include written check line for items inspected, inspection results, acceptance criteria, non-compliance remarks, inspectors signature and company affiliations.

Tasks and responsibilities

- Definitions for task, functions, and responsibilities of each party and for each activity need to be established.
- Tasks and functions should include the total scope as well as any limitations of both technical and organizational rules.

Guide lines for users

- Guarantees for the users including inabilities for faults, should be fully conversed by the contract and in some cases, by the building (contract) control system.

3. Discuss in detail about the thermal properties of concrete.

The three important thermal properties of concrete are,

- Thermal conductivity of concrete.
- Co-efficient of thermal expansion and
- Fire resistance

Thermal character of concrete

- The process of hydration of cement materials releases heat which raises the temperature of concrete. This heat must eventually be lost to the atmosphere and the concrete temperature has to reach equilibrium with a long term atmospheric conditions.
- The atmospheric gradients may occur or develop in the concrete as the internal temperature is raised above the surface temperature of the concrete member. The surface temperature is dependent on the material in contact. The resulting temperature will produce tensions on the surface and may be stiffness to cause cracking.

Thermal conductivity of concrete

- Thermal conductivity of heat is the ability of the materials to conduct heat.
- Heat is defined as the ratio of the flow of heat to the atmospheric gradient and this thermal conductivity is measured in Joules per second per square meter.
- The thermal conductivity of heat depends on the composition with respect to the type of aggregate amount of it and moisture content.

- When the concrete is saturated, the conductivity ranges from 1.4 and 3.6 m/sec.
- The thermal conductivity varies more rapidly in light weight concrete than heavy or normal weight concrete.

Thermal expansion of concrete

- Coefficient of thermal expansion of concrete is an important property which affects the stability and durability at different temperature conditions.
- As the concrete is made up of two phase material namely paste and aggregate paste, which has dissimilar thermal co-efficient but the coefficient of concrete is a resultant of these two phases.
- In general form, the coefficient of thermal expansion of concrete is a I function of the quantity of aggregate in the mix and the coefficient of thermal expansion of aggregate by itself.

Fire resistance

- Even concrete is not a refractory material but a combustible one and has good lire resisting properties.
- Fire resistance of concrete is determined by three factors.
- The capacity of concrete itself to with stand heat.
- The subsequent action of water without losing strength or unduly without cracking or spalling.
- And the conductivity of the concrete to heat and coefficient of thermal expansion of concrete.

Action of fire on (concrete) steel

- The fire introduces high temperature gradients and as a result of it, the surface layers extend to separate and spall off from the cooler interior.
- The heating of reinforcement aggravates the expansion both laterally and longitudinally of the reinforcement base resulting in loss of bond and loss of strength of reinforcement.

Fire resistance on concrete

- Fire on concrete building damages the concrete as well as steel reinforcement, causing disintegration of the concrete and buckling of steel.

- The temperature gradient is extreme 30 to 40°C on the outer face and above 800'C on the interface (near the source of fire).
- In the initial stage (half an hour) as the heat inside builds up, some aggregate, expand suddenly, spalling the adjacent concrete. Moisture in concrete rapidly changes to steam, causing localized bursting of small pieces of concrete. Extreme heat near the sources of fire causes spalling rapidly expanding concrete surfaces.
- In the next 30 minutes the temperature inside reaches 400°C. the cement matrix gets converted causing disintegration of concrete. The reinforcing steel loses the tensile capacity at such temperatures. Deflection of beams and slab increases beyond this limit.
- Beyond one hour of fire, as the concrete disintegrates, the exposed steel expands; more rapidly than the surrounding concrete causing buckling, loss of bond to adjacent concrete.
- The thermal conductivity of any concrete can be calculated from

$$K = Km\,(2m - m^2) + km\,k_2\,\frac{(1-m)^2}{K_2M} + Km\,(1-m)$$

K = conductivity of aggregate

Km = conductivity of mortar

Thermal effects on concrete:

- Excess water in concrete evaporates due to heat and setting of concrete occurs. The loss of moisture due to evaporation causes the cement paste matrix to contract, leading to shrinkage stress.
- A 6m long slab may shrink 3 mm to 5 mm along its length called "**drying shrinkage**".
- If the slab is supported at both its ends, stress build up due to shrinkage drying may exceed the tensile strength of concrete, resulting in a 3 mm to 5 mm wide crack.
- However if the concrete is properly reinforced at regular intervals, the shrinkage stress are distributed along the length of slab, resulting infirmly spaced fine cracks.

4. Elaborately explain about the effect of temperature on concrete.

- Similar to other materials, concrete expands with increase in temperature and contracts with decrease in temperature. The range of variation in temperature vanes from localities to localities, season to season and day to day.
- The objectionable cracks may occur in concrete due to contraction combined with the effect of shrinkage.
- Occasionally large and harmful stress may develop due to deformation because of temperature changes.
- The coefficient of thermal expansion of concrete depends on the type and quantity of cement, aggregate, relative humidity and sizes of section.

Concrete at high temperature

- In some industrial applications such as aluminium plants and brick works, the concrete may be occasionally or frequently subjected to temperatures. These temperatures are likely to be applied linearly.
- Generally with and rather a long period.
- Similarly jet aircraft and vertical take aircraft may subject the pavement to very high temperature.
- Heat may affect concrete.
- The removal of evaporable water
- The removal of combined water.
- Alteration of cement paste.
- Disruption (of beam) from disparity of expansion and resulting thermal stresses.
- Alteration of aggregate.
- Change of the bond between aggregate and paste.
- Other effects on concrete due to temperature.
- Cycles of temperature can have a progressive effect on the reduction of strength even longer curing did not improve the loss.

- During rapid rise and fall of temperature, the response of concrete is affected by the interaction of thermal expansion, drying thermal incompatibility and these get enhanced at very at high temperatures.
- If the heating is sufficiently rapid, high stresses can be induced, hence failure and instability may result.

Effects on steel at high temperature

- The influence of temperature on steel appears as a change in yield stress, ultimate strength and modulus of elasticity.
- The changes depend on the type of steel and are greater in cold-weathered steel.
- The strength of hot-rolled steel bars are not reduced if the temperature does not reach to 300°C. But at temperature of 500-600°C the yield stress is reduced to the order of the working stress and the elastic modulus is reduced by one-third.
- Bars heated to this temperature virtually recover their normal temperature.
- Bars heated to 800°C have a lower residual strength after cooling to room temperature.
- Pre-stressing wire and strand starts to lose strength at 150°C and may have only 50% of its room temperature strength when heated to about 400°C.

Behaviour of fire

- Failure in a fire occurs either through the spread of fire from the compartment or through structural failure of a member or assembly of members.
- Structural railer of a member most frequently occurs when the temperature of the steel reduces the yield stress to the working stress.
- The length of time of this fire occurs depending upon the severity of fire, the thermal conductivity of the protecting concrete and weather spalling of the protection covers.

5. Explain the various corrosion protection methods.

Methods of corrosion protection:

- Corrosion inhibitors.
- Corrosion resisting steels.

- Coatings for steel and,
- Cathodic protection.
- Corrosion inhibitor is an admixture that is used in concrete to prevent the metal embedded in concrete from corroding.

Types of inhibitors

- Anodic inhibitors: (alkalis, phosphates, chromates, nitrates, benzoates).
- Anodic inhibitors function by decreasing the reaction at the anode.
- They may react with the existing corrosion product to form an extremely insoluble adherent coating on the metal surface.
- Organic inhibitors replace water at site on the inner plate, thus decrease corrosion.

Cathode inhibitors (calcium carbonate)

- Aluminium oxide and magnesium oxide.
- Cathode inhibitors act to stifle the cathode reaction.
- They are generally less effective since they do not form films on the anode.

Mixed inhibitors

- A mixed inhibitor may affect both the anode and cathode processes

Dangerous and safe inhibitors

- A safe inhibitor is defined as one which reduces the total corrosion without increasing to area: while dangerous inhibitors produce increased rates due to the lack of sufficient inhibitors to prevent complete protection or the presence of crevices into which the inhibitor does not rapidly diffuse
- Anodic inhibitors are generally dangerous except sodium benzoate.
- Cathode inhibitors are generally sale, but sulphate is an exception.

Classification of inhibitors

Somewhat a different classification based on the actions such as.

- Barrier layer formation.
- Neutralization and
- Salvaging.

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These represent processes by way of which the passivation is achieved: It is interesting to note that the barrier layer formation is generally best achieved by simply coating steel with a low water cement paste which needs no extra admixture at all.

Corrosion resisting steel

- In mild steel, the corrosion is not affected by composition, grade or level or stresses. Hence substitute steels for corrosion resistance will have a significantly different composition.
- Based on some atmosphere, corrosion weathering, steels of corral type were tested in concrete. They did not perform well in most content containing chloride, it is observed that although the total amount of corrosion is less than that would occur on high yield steel under similar conditions, deep localized pitting is developed, which could more structurally weaken the structure.
- Stainless steel pipe has been used for special applications especially as flames in precast members, but generally not expect use as a substitute for mild steel any case, resistant.
- Stainless steel contains relatively lower content of chloride levels, this was based in a delayed time to cracking relative to that for high strength steels, but this was offset by irregular pitting corrosion. Very high corrosion resistance was shown by austenitic stainless steels in all the environments in which they were tested, but the observation of some very high pitting in the preserve of chlorides lead to the warning the corrosion susceptibility was not evaluated in the test programme.

Coating of steel

- Coatings are sometimes considered as for mild steel is to be embedded in concrete exposed to adverse corrosive condition.
- There are both benefits and disadvantages to their use and any benefit can only be optimized by carefully considering the specific job. The more obvious of those considerations are:
- Do the expected service life and structural exposure warrant coating of the steel.
- If coating is desirable, is the field job ready or whether the coating be applied prior to fabrications of the reinforcing for the structure.

- Do transportation and subsequent lubrication pose a significant danger to the coating.
- In view of the exposure conditions, is the choice of coating' dictated by these conditions rather than adoption of other measures.

Groups of coating

Organic coating

- Organic coatings include coal tar, enamel, epoxy, asphalt, chlorinated rubber, vinyl, phenolic, neoprene and methane.
- Out of these, epoxy group appears to have the best potential for use.

Epoxy coatings

- Epoxy coatings provide excellent corrosion protection of prestressing steel.
- The epoxies are wear resistance.
- Epoxies are used to protect the steel reinforcing bars embedded in concrete of bridge decks from rapid corrosion. This corrosion is caused by the chloride ions from the most commonly applied salts, sodium chloride and calcium chloride.
- Results obtained from epoxy and polyvinyl chloride coatings, if properly applied could be expected to adequately protect steel reinforcing bars from corrosion.
- However only the epoxy coated bars had acceptable bond and creep characteristics when embedded in concrete.
- The powder epoxy coatings overall performed better than the liquid epoxies and epoxy coatings were identified as promoting materials to be used on reinforcing steel bars embedded in concrete bridges.
- The epoxy coat acts (as) to isolate the steel bars from contact with oxygen, moisture and chloride. However, at damaged point on the corrosion may concrete, commence, such damage exists on the bar coupled to uncrated steel the performance of such bar is still considered to be satisfactory.
- The slab specimen showed little difference on crack width, spacing, deflections or ultimate strength for coated and un-coated bar. The slab containing epoxy-coated bar generally failed in flexure rather than in bond at approximately 4% lower loads than with uncrated bar.

- The beam specimen in which flexural type loads where applied to the reinforcing bars splitting occurred along the reinforcing bars, but failure was primarily by either pull out or yielding of the embedded steel.
- Organic coatings other than epoxy have occasionally been used. In Germany, PVC has been used on welded wire fabric.

Metallic coating

- Metallic coatings are capable of providing protections to the black steel on one of two ways.
- Metals with a more negative corrosion potential than steel stich as zinc, and cadmium, provide sacrificial protection to the steel embedded in concrete, although the development of passivating products on the coating is of significance in the longer time steels and alloys with a loss negative corrosion potential (more able) than the bar steel, such as nickel and stainless steel, protect the reinforcement only as long as the coating is unbroken since the bar steel is anodic to the coating. The steel is protected by such metals simply by encapsulation.
- Metallic coating is limited to galvanizing material.
- Coating of metals under mass exposure conditions, as in the presence of conditions, zinc coating does not always provide increased protection.
- Cadmium suffers from a cost disadvantage when compared to zinc and the derivatives are slightly toxic.

Other coatings

- Zinc coating.
- Zinc coating is used where longer life protection is desired than can be provided by usual methods of coating it is not a permanent protection, however and in moist, tropical climates the galvanized coating itself is usually protected with a good-quality paint. Galvanizing is also useful for subaqueous exposure, where it gives fairly good protection.
- For structural work, it is customary to specify zinc coating by the hot-dip process (galvanizing), because the resulting coating is thicker than that applied by their processes such as the radioing, electroplating or spraying.

Cathodic protection

- Corrosion in corrosive environments or in damp soil is primarily electrochemical in nature and is due to a current passing from anodic areas of the metal into solution and returning to the metal at cathode areas. This type of corrosion can bo prevented by impressing a countercurrent on the metal in sufficient amount to neutralize the aggressive electric currents.
- Cathodic protection, which consists of the electrical connections of the final anode to the structure to be protected, serves this function by neutralizing the corroding current and forming layers of insoluble reaction products on the new cathode areas.
- In structural applications, cathodic application of buried steel (pipe or piling) for protection of the submerged portions of mass structure such as piling and bracing for protecting lock gates, for the interior of water tanks and for the exterior of hurried tanks.
- Cathodes protection however will not prevent corrosion of structure unless the metal to be protected is surrounded by a electrolyte such as water or damp soil and is ineffective in protecting structural elements above the water line or in very dry soil. In cathode protection, the effects of the induced currents on adjacent structures may be damaged unless they are adequately bonded to the new system or other means of protections are provided.

6. Discuss the factors that contribute to the failure of concrete structures.

1. Incorrect Selection of Materials

The concrete mix required should be selected to meet the environmental or soil conditions where the concrete is to be placed. The minimum grade that should be used for reinforced concrete is grade 30. Higher grades should be used for some foundations and for structures near the sea or in an aggressive industrial environment. If sulphates are present in the soil or ground water, sulphate-resisting Portland cement should be used. Where freezing and thawing occurs air entrainment should be adopted.

2. Errors in Design Calculations and Detailing

An independent check should be made of all design calculations to ensure that the section sizes, slab thickness etc. and reinforcement sizes and spacing specified are

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2. Errors In Design Calculations and Detailing

An independent check should be made of all design calculations to ensure that the section sizes, slab thickness etc. and reinforcement sizes and spacing specified are adequate to carry the worst combination of design loads. The check should include overall stability, robustness and serviceability and foundation design.

Incorrect detailing is one of the commonest causes of failure and cracking in concrete structures. First the overall arrangement of the structure should be correct, efficient and robust. Movement joints should be provided when required to reduce or eliminate cracking. The overall detail should be such as to shed water.

Internal or element detailing must comply with the code requirements. The provisions specify the cover to reinforcement, minimum thicknesses for fire resistance, maximum and minimum steel areas, bar spacing limits and reinforcement to control cracking, lap lengths, anchorage of bars etc.

3. Poor Construction Methods

The main items that come under the heading of poor construction methods resulting from bad workmanship and inadequate quality control and supervision are as follows. BS 8110, clause 6.2 gives guidance on many of the aspects discussed below.

(i) Incorrect placement of steel

Incorrect placement of steel can result in insufficient cover, leading to corrosion of the reinforcement. If the bars are placed grossly out of position or in the wrong position, collapse can occur when the element is fully loaded.

(ii) Inadequate cover to reinforcement

Inadequate cover to reinforcement permits ingress of moisture, gases and other substances and leads to corrosion of the reinforcement and cracking and spalling of the concrete.

(iii) Incorrectly made construction joints

The main faults in construction joints are lack of preparation and poor compaction. The old concrete should be washed and a layer of rich concrete laid before pouring is continued. Poor joints allow ingress of moisture and staining of the concrete face.

(iv) Grout leakage

Grout leakage occurs where formwork joints do not fit together properly. The result is a porous area of concrete that has little or no cement and fine aggregate. All formwork joints should be properly sealed.

(v) Poor compaction

If concrete is not properly compacted by ramming or vibration, the result is a portion of porous honeycomb concrete. This part must be backed out and recast. Complete compaction is essential to give a dense, impermeable concrete.

(vi) Segregation

Segregation occurs when the mix ingredients become separated. It is the result of

1. dropping the mix through too great a height in placing. Chutes or pipes should be used in such cases.
2. using a harsh mix with high coarse aggregate content.
3. large aggregate sinking due to over-vibration or use of too much plasticizer Segregation results in uneven concrete texture, or porous concrete in some cases.

(vii) Poor curing

A poor curing procedure can result in loss of water through evaporation. This can cause a reduction in strength if there is not sufficient water for complete hydration of the cement. Loss of water can cause shrinkage cracking. During curing the concrete should be kept damp and covered. See BS 8110, clause 6.2.3 on curing.

(viii) Too high water content

Excess water increases workability but decreases the strength and increases the porosity and permeability of the hardened concrete, which can lead to corrosion of the reinforcement. The correct water-to-cement ratio for the mix should be strictly enforced.

4. Chemical Attack

To main causes of chemical attack on concrete and reinforcement can be classified under the following headings.

(i) Chlorides

High concentrations of chloride ions cause corrosion of reinforcement and the products of corrosion can disrupt the concrete. Chlorides can be introduced into the concrete either during or after construction as follows.

(i) Before construction Chlorides can be admitted in admixtures containing calcium chloride, through using mixing water contaminated with salt water or improperly washed marine aggregates.

(ii) After construction Chlorides in salt hr sea water, in airborne sea spray and from deicing salts can attack permeable concrete causing corrosion of reinforcement,

(ii) Sulphates

Sulphates are present in most cement and some aggregates. Sulphates may also be present in soils, groundwater and sea water, industrial wastes and acid rain. The products of sulphate attack on concrete occupy a larger space than the original material and this causes the concrete to disintegrate and permits corrosion of steel to begin. Sulphate-resisting Portland cement should be used where sulphates are present in the soil, water or atmosphere come into contact with the concrete. Super sulphated cement, made from blast furnace slag, can also be used. This cement can resist the highest concentrations of sulphates.

(iii) Carbonation

Carbonation is the process by which carbon dioxide from the atmosphere slowly transform calcium hydroxide into calcium carbonate in concrete. The concrete itself is not harmed and increases in strength, but the reinforcement can be seriously affected by corrosion as result of this process.

Normally the high pH value of the concrete prevents corrosion of the reinforcing bars by keeping them in a highly alkaline environment due to the release of calcium hydroxide by the cement during its hydration. Carbonated concrete has a pH value of 8.3 while the passivation of steel starts at a pH value of 9.5. The depth of Carbonation in good dense concrete is about 3 mm at an early stage and may increase to 6-10 mm after 30-40 years. Poor concrete may have a depth of carbonation of 50 mm after say 6-8 years. The rate of carbonation depends on time, cover, concrete density, cement content, water-to-cement ratio and the presence of cracks.

(iv) Alkali-silica reaction

A chemical reaction can take place between alkali in cement and certain forms of silica in aggregate. The reaction produces a gel which absorbs water and expands in volume, resulting in cracking and disintegration of the concrete. The reaction only occurs when the following are present together:

1. A high moisture level in the concrete
2. Cement with a high alkali content or some other source of alkali
3. Aggregate containing an alkali-reactive constituent